

Interactive
Comment

Interactive comment on “Seasonal distributions and fluxes of ²¹⁰Pb and ²¹⁰Po in the Northern South China Sea” by C.-L. Wei et al.

Anonymous Referee #2

Received and published: 24 September 2014

General comments: Subtle difference in biogeochemical behavior between ²¹⁰Po and ²¹⁰Pb, poorly understood, has been proposed especially in oligotrophic seawaters. Targeted researches would improve our better understanding of ²¹⁰Po and ²¹⁰Pb in such an environment. In this paper, the authors present a clear framework of seasonal variability of both ²¹⁰Po and ²¹⁰Pb in the whole water column in the South China Sea (SCS). They show the difference between ²¹⁰Po and ²¹⁰Pb in vertical profiles, partitioning, residence time, and fluxes. Using SS and NSS models, this paper shows the influence of models on the quantification of ²¹⁰Po and ²¹⁰Pb exports. The findings of consistent ²¹⁰Pb fluxes and inconsistent ²¹⁰Po fluxes between sediment trap and radionuclide technique reveal the dominant control of biological activities over

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the disequilibrium between ^{210}Po and ^{210}Pb . These results provide supports to the $^{210}\text{Po}/^{210}\text{Pb}$ as a biogenic particulate flux proxy in the SCS and in other oligotrophic settings. Therefore this paper is very welcomed.

The authors propose that sporadic events is responsible for the inconsistency between $^{210}\text{Po}/^{210}\text{Pb}$ derived ^{210}Po fluxes and sediment trap values. It could be the truth I believe. Essentially, this difference illustrates the different fluxes over different timescales. Sediment trap is deployed here in a very narrow time-window, while $^{210}\text{Po}/^{210}\text{Pb}$ disequilibria usually record the information over a much longtime. Stressing on this point could facilitate wide readers' understanding. ^{210}Po excess in the subsurface waters is the additional difference in behavior from ^{210}Pb , as shown in Figure 6. This characteristic indirectly supports the close relation between ^{210}Po and biogenic particles and the application of $^{210}\text{Po}/^{210}\text{Pb}$ to track biogenic matter. More elaboration would clarify the different biogeochemical behavior between ^{210}Po and ^{210}Pb in oligotrophic environments.

Specific comments: The title of Figure 3, the last sentence, change “ ^{210}Pb relative to ^{210}Pb ” to “ ^{210}Po relative to ^{210}Pb ”.

Figure 8, the legends of SS and NSS for ^{210}Pb and ^{210}Po are the same.

Page 11, line 23, Fig. 8a and b with respect to the relationship between K_d values and TSM do not seem to be presented in the manuscript.

Interactive comment on Biogeosciences Discuss., 11, 11533, 2014.

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Reply to anonymous referee #1

The favorable review of the anonymous referee is very much appreciated. The manuscript has been edited accordingly and the revisions are listed below:

- The typo in the caption of Fig. 3 was corrected.
- Only steady-state (SS) and non-steady-state (NSS) calculations of scavenging and removal fluxes of ^{210}Po are shown in Fig. 8. Fluxes of ^{210}Pb were not shown in the figure.
- Fig. 8a and b present the results of scavenging (J flux) and removal (F flux) fluxes of ^{210}Po calculated by SS and NSS at 1000m and 2000m. Although indirectly correlated, these fluxes do not show systematic relationship with either partitioning coefficient (K_d) or suspended matter concentration (TSM).
- The discrepancy between measured and modeled ^{210}Po fluxes was attributed to episodic event of particle sinking, which may be missed by the limited sediment trap sampling. The process of different time scale that can be observed by the two methodologies, i.e., sediment trap and disequilibria, was mentioned in the revised manuscript.

Interactive comment on “Seasonal distributions and fluxes of ²¹⁰Pb and ²¹⁰Po in the Northern South China Sea” by C.-L. Wei et al.

P. Santschi (Referee)

santschi@tamug.edu

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Review of Wei et al.

The paper by Wei et al. reports on seasonal distributions and fluxes of Pb-210 and Po-210 in the Northern South China Sea. One of its major goals is to resolve the discrepancy between vertical distributions of Pb-210 and Po-210 between different studies, and between radionuclide fluxes calculated from water column distributions and those measured by sediment traps. I would like to discuss some methodological aspects, as well as the assessment of the study's major goal.

Methods: The methods used in the sediment trap exposures of 15 days, mentioned
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on p. 11548, needs to be elaborated more in the methods section (e.g., addition of poisons, sampling details, etc). Furthermore, it should be mentioned that any apparent “dissolution” of radionuclides into the water during exposure and incubation in the traps had (apparently) not been directly assessed.

Residence time discussion (page 11549-11550): residence times of Pb-210 would be expected to be a function of depth in semi-enclosed basins, e.g., as had been shown for the Gulf of Mexico (Baskaran, M., and Santschi, P.H. 2002. Particulate and dissolved 210Pb activities in the shelf and slope regions of the Gulf of Mexico waters. *Continent. Shelf Res.*, 22, 1493-1510.), e.g., about 3 years for 1000m, and 6 years for 2000m (and by inference, 11 years for 3500m). These previously determined values for the Gulf of Mexico would compare favorably to the 12-17 years that the authors obtained for the SCS region at 3500m.

Discrepancy of calculated vs. measured Po-210 fluxes. There exists an apparent disagreement between Po fluxes determined in sediment traps and those calculated from inventories of 210Po and 210Pb, with trap fluxes amounting to only about 10% of calculated Po-210 fluxes, and about 50% of calculated Pb-210 fluxes. However, this apparent disagreement between Po fluxes determined in sediment traps and those calculated from inventories of 210Po and 210Pb has yet another explanation that might be more likely: The most likely source of bias is that particulate radionuclides are regenerated into solution (“dissolved”) during the 15 days exposure, and the number of months those particles are sitting in the sediment trap cups. Unfortunately, most aquatic scientists are unaware of this potential artifact.

The authors might want to consider mentioning here that there actually exist a small number of studies that previously have pointed out the great need to include the fraction of selected radionuclides (and metal ions) that is “dissolved” during sediment trap exposure. Without such corrections, measured radionuclide fluxes can be in great error. For example, 50% of Po-210 (but ~0% of Pb-210 and Be-7) was released into the overlying solution during 2-3 week sediment trap exposure (50 and 130m depth) in a

Swiss lake, as documented by Schuler et al. (1991). While this was carried out in a lake, I suspect that the effect would be similar or worse in the ocean. This suspicion is based on the documented release of Th-234 (considered a “particle-reactive” isotope) into the overlying water during short-term (1 day) sediment trap exposures (at 65-140 m depth), as documented by Hung et al. (2010) and Xu et al. (2011). This documented loss of Th-234 (~75%) and organic carbon (~50%) necessitated major corrections of measured fluxes. While these large losses were documented in the upper 150 m of the water column, ²¹⁰Po losses could occur also below that depth, like in this ms at 700-3500 m depth. At the very least, this potential loss term needs to be discussed and assessed. Po-210 loss during collection and processing is at least as plausible as a sporadic washout by calcareous ballasts that the authors proposed, which, for some unknown reason, would greatly fractionate between Po-210 and Pb-210. .

Relevant references pointing out the need of correcting natural radionuclide fluxes for dissolution in sediment traps:

Polonium:

Schuler, Ch., Wieland, E., Santschi, P.H., Sturm, M., Lück, A., Farrenkothen, K., Bollhalder, S., Beer, J., Bonani, G., Hofmann, H.J., Suter, M., and Wölfli, W. 1991. A multi-tracer study of radionuclides in Lake Zurich, Switzerland 1. Comparison of atmospheric and sedimentary fluxes of ⁷Be, ¹⁰Be, ²¹⁰Pb, ²¹⁰Po and ¹³⁷Cs, *J. Geophys. Res.*, 96 (C9),17051-17065. Loss of ²¹⁰Po, but not of ²¹⁰Pb and ⁷Be, is documented on page 17061.

Thorium:

Hung, C.-C., Xu, C., Santschi, P.H., Zhang, S., Schwehr, K.A., Quigg, Guo, L., Gong, G.-C., A., Pinckney, J., Long, R., and Wei, C.-L. 2010. Comparative evaluation of sediment-trap and ²³⁴Th-derived POC fluxes from the upper oligotrophic waters of the Gulf of Mexico and the subtropical northwestern Pacific Ocean. *Mar. Chem.*, 121, 132–144.

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Xu, C., Santschi, P. H., Hung, C.-C., Zhang, S. , Schwehr, K.A., Roberts, K.A., Guo, L.D., Gong, G.-C., Quigg, A., Long, R., Pinckney, J., Duan, S.W., Amon, R., Wei, C.-L. 2011. Controls of Th-234 removal from the oligotrophic ocean by polyuronic acids and modification by microbial activity. *Marine Chemistry*, 123, 111–126.

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Reply to Dr. P. Santschi

Thanks for Dr. Santschi's constructive comments. Indeed, the possibility of underestimating the ^{210}Po flux due to particle degradation during the deployment cannot be ruled out. Except Heussner et al. (1990), we are aware that the regeneration of ^{210}Po from degradation of trap particles was not checked in existing literature. We have recently obtained a new batch of trap samples, including trap solution, collected from the SEATS. The samples are currently being measured for ^{210}Po level in the trap solution of each cup. The regeneration issue will then be resolved once the data is available.

In response to the constructive comments of Dr. Santschi, we have made revision of the manuscript, which are summarized below:

- More detailed description of the sediment trap sampling was given in method.
- The residence time of ^{210}Pb in the Gulf of Mexico was also compared with that in the SCS.
- Some discussion on the regeneration issue is added when the discrepancy between the modeled and measured ^{210}Po flux was described.

Heussner, S., R. D. Cherry, and M. Heyraud (1990), ^{210}Po , ^{210}Pb in sediment trap particles on a Mediterranean continental margin, *Cont. Shelf Res.*, 10, 989-1004.